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A NUMERICAL EVALUATION TECHNIQUE FOR WEIGHTING MULTIPLE OPTIONS

A TECHNICAL MEMORANDUM

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ABSTRACT

This paper describes a numerical evaluation technique for weighting multiple options. It is a very simple, but useful, technique for systematically applying relative weights to any number of options. To make the process clear and understandable to a wide variety of readers, the technique is applied to the purchase of a new automobile. A numerical evaluation of the optional equipment on an automobile is made.

The numerical evaluation technique may be applied to a wide variety of multiple-option problems. The technique can be applied to weight multiple objectives, requirements, priorities, methods, or practically any set of attributes. Subjectivity is not eliminated by the process, but it is systematized to allow a uniform and unbiased approach. It has important application in the systems analysis field, particularly in weapons systems evaluations, requirements analysis and logistical analysis.

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I. INTRODUCTION

Systems analysis largely involves the task of assisting decisionmakers in choosing preferred future courses of action from several alternatives. Maximum use is made of quantitative techniques. Often, however, quantitative analysis is not feasible. Many intangible alternatives must be analyzed in a subjective manner. Subjective analysis involves value judgements by the decisionmaker and thus is specific to the individual performing the analysis. This does not mean that the subjective evaluation must be capricious, although it often is. A subjective analysis, although variable among inidividuals performing the analysis, can still be selfconsistent and systematic.

Whether we realize it or not, we all perform systems analysis in our everyday lives. For most people, the technique is one of subjective analysis with limited quantitative inputs (usually cost) also considered. We are often confronted with the necessity of choosing among several alternatives and many combinations of alternatives. Trying to analyze too many variables at once becomes a bewildering task. The frustration of grappling with complex choices invites one to "give up" and make the decision in a haphazard manner. Such a decision usually gives less-than-optimum results and often winds up costing the decisionmaker money and inconvenience which he can ill afford. Such problems can

be minimized by using a systematic approach to a subjective evaluation of multiple options. It is the goal of this paper to describe one such approach.

II. THE PROBLEM

A common decision involving several options and combinations of options is the determination of the optional equipment to include in the purchase of a new automobile. Clearly the decision must be subjective. Options that are important to one buyer may be completely unimportant to another. This is the very reason that the equipment is optional - - - to allow the buyer to choose the combination which subjectively suits his needs.

Suppose the buyer, Mr. Jones, has decided that he wants to buy an intermediate size sedan. The basic car comes equipped with a six cylinder engine, standard manual transmission and precious little else. The manufacturer lists about twenty options which can be added, at additional expense, to the basic car. Suppose Mr. Jones is only interested in 14 of those 20 options. Some options cost little and some cost much. Some he wants very much, and others he's not so sure about. Mr. Jones is no mathematical wizard and cannot juggle all 14 costs and their relative importance in his mind simultaneously. Let's see how the systems analyst can come to Mr. Jones's aid.

First the systems analyst lists the fourteen options in which Mr. Jones indicated an interest. Each of these options is given a key letter. These are just assigned sequentially, and the order makes no difference. Next, the systems analyst makes up an evaluation matrix using the key letters. The matrix is made up so that one square exists for every possible pairing of key letters. Figure 1 is the basic matrix prepared for Mr.Jones. The top half of Figure 1 contains the options and key letters; the bottom half the key letter matrix. Ignore the "weight" column for the present.

III. THE NUMERICAL EVALUATION

With Figure 1, the analyst is now ready to have Mr. Jones make the evaluation. Starting with key letter "A", Mr. Jones is asked to compare that option (8 cylinder engine) to each of the other options. He is asked to indicate, first, his preference between each pair of options and, secondly, the extent of his preference. The extent of his preference is shown by a "1", "2" or "3", as explained in the note on Figure 1. Usually these preferences are a function of how long it takes or how hard it is for Mr. Jones to decide which option he prefers. If his reaction is immediate it would probably be a "3". If he has to

NUMERICAL EVALUATION TECHNIQUE

Name ________________ Date __________ Project ____________________

EVALUATION SUMMARY

KEY LETTER	Options	WEIGHT
A	8 CYLINDER ENGINE	
B	AUTOMATIC TRANSMISSION	
C	TRACTION TYPE DIFFERENTIAL	
D	HEAVY DUTY SUSPENSION	
E	DISC BRAKES	
F	POWER STEERING	
G	POWER WINDOWS	
H	POWER DOOR LOCKS	
I	POWER ANTENNA	
J	AIR CONDITIONER	
K	AM RADIO	
L	FM STEREO RADIO	
M	AUTOMATIC SPEED CONTROL	
N	SUN ROOF	

	B	C	D	E	F	G	H	I	J	K	L	M	N
A													
B													
C													
D													
E													
F													
G													
H													
I													
J													
K													
L													
M													

NUMERICAL EVALUATION

<u>NOTE:</u> – EVALUATION WEIGHT FACTORS

1 = MINOR DIFFERENCE IN IMPORTANCE
2 = MEDIUM DIFFERENCE IN IMPORTANCE
3 = MAJOR DIFFERENCE IN IMPORTANCE

Figure 1. Basic Evaluation Matrix

give it some thought, but clearly prefers one alternative, then he would assign a "2". If he has a very difficult time deciding, then a "1" would be assigned. The preferred option is named by its key letter followed by the extent of preference. For example a "B-1" in the A-B intersection block of Figure 1 means that in comparing options A and B, Mr. Jones preferred options B but was not very sure about his decision. Repeating this process for the entire matrix required Mr. Jones to compare each option against every other option. None could be skipped and during the process it would be very difficult for Mr. Jones to anticipate the final outcome. The completed matrix is shown in Figure 2. The "weight" column in Figure 2 is the desired output of the evaluation. The weights are simply the summation of the preference ratings for each key letter obtained by adding all the numbers associated with each respective key letter. For example, in Figure 2 there was a total of 29 "preference points" associated with key letter "A".

The weights obtained from the matrix evaluation process represent the relative preference that Mr. Jones had for the fourteen options. Examination of the weights shows that Mr. Jones has the strongest preference for an automatic transmission, followed by an eight-cylinder engine, and then by air conditioning. The zero rating on the power antenna shows that he preferred every option to it. With the weights in Figure 2, Mr. Jones now has a credible

NUMERICAL EVALUATION TECHNIQUE

Name Mr. Jones Date 1/2/75 Project New Auto

EVALUATION SUMMARY

KEY LETTER	Options	WEIGHT
A	8 CYLINDER ENGINE	29
B	AUTOMATIC TRANSMISSION	32
C	TRACTION TYPE DIFFERENTIAL	16
D	HEAVY DUTY SUSPENSION	16
E	DISC BRAKES	23
F	POWER STEERING	26
G	POWER WINDOWS	4
H	POWER DOOR LOCKS	2
I	POWER ANTENNA	0
J	AIR CONDITIONER	28
K	AM RADIO	11
L	FM RADIO	18
M	AUTOMATIC SPEED CONTROL	10
N	SUN ROOF	6

NUMERICAL EVALUATION

	B	C	D	E	F	G	H	I	J	K	L	M	N
A	B-1	A-3	A-2	A-2	A-1	A-3	A-3	A-3	J-1	A-3	A-3	A-3	A-3
B		B-3	B-2	B-2	B-2	B-3	B-3	B-3	B-1	B-3	B-3	B-3	B-3
C			D-1	E-2	F-3	C-3	C-3	C-3	J-3	C-1	C-1	C-2	C-3
D				E-2	F-2	D-3	D-3	D-3	J-2	D-1	L-1	D-2	D-3
E					F-1	E-3	E-3	E-3	J-1	E-2	E-1	E-3	E-3
F						F-3	F-3	F-3	F-1	F-2	F-2	F-3	F-3
G							G-2	G-2	J-3	K-2	L-3	M-2	N-1
H								H-2	J-3	K-3	L-3	M-3	N-2
I									J-3	K-3	L-3	M-3	N-3
J										J-3	J-3	J-3	J-3
K											L-3	K-1	K-2
L												L-2	L-3
M													M-2

<u>NOTE:</u> – EVALUATION WEIGHT FACTORS

1 = MINOR DIFFERENCE IN IMPORTANCE
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3 = MAJOR DIFFERENCE IN IMPORTANCE

Figure 2. Completed Evaluation Matrix

priority list of options and using just this list alone, is in a much better position to make rational choices. If he had a limit on his funds, he could select those options with the highest weight first, regressing down the priority list until his funds were expended. Thus, Mr. Jones is able to make rational and relatively painless decisions on the options without his having the nagging feeling that he had overlooked something.

The example could be pushed a step further to more clearly consider the costs of the options. Some options are very expensive while others are relatively inexpensive. With limited funds, can Mr. Jones get the most satisfaction from one expensive option or from several inexpensive options? If we consider the weights as indicators of Mr. Jones's relative utility (or satisfaction), then we can see how many "utility points per buck" he is getting for each option. Table 1 shows these values calculated for the 14 options in the example. The ratios are multiplied by 100 for convenience because it is easier to deal with whole numbers than with fractions.

Examination of Table 1 shows a quite differenct picture than just considering the weights by themselves. It can be seen that the heavy duty suspension provides the most utility per buck, followed by disc brakes and the traction-type differential. What does this mean? Mr. Jones still

Table 1. Utility Rates for Each Option

OPTION	WEIGHT	COST ($)	UTILITY PER DOLLAR*
8 Cylinder Engine	29	128	23
Automatic Transmission	32	227	14
Traction-Type Differential	16	50	32
Heavy Duty Suspension	16	31	52
Disc Brakes	23	51	45
Power Steering	26	118	22
Power Windows	4	124	3
Power Door Locks	2	70	3
Power Antenna	0	34	0
Air Conditioner	28	414	7
AM Radio	11	63	18
FM Radio	18	213	9
Automatic Speed Control	10	113	9
Sun Roof	6	481	1

*Defined as $\frac{100 \times \text{Weight}}{\text{Cost}}$

prefers an automatic transmission. However, if his funds are very limited, he would be getting more utility (or satisfaction) per dollar from the heavy duty suspension. Again, this gives additional data to Mr. Jones to allow him to make a rational decision and to make an efficient allocation of his resources. The evaluation does not make the decision for Mr.Jones, but it does gives him a systematic and rational basis for making the decision.

IV. APPLICATIONS TO DEFENSE

The new car example shows the usefulness of the numerical evaluation technique. If the technique was only applicable to buying a new car it would be of little concern to the systems analyst. Besides, one fast-talking, high-pressure salesman could blow the whole process. It does not take much imagination to see how the technique can profitably be applied to defense projects. For example, let the new car options become the required operational requirements (ROC) of a combat vehicle. Let Mr. Jones become the key managers of TACOM. Then the process would yield relative weights of the various ROC's. These weights could be used in a variety of ways. For example several candidate vehicles could be rated, say on a scale of 1 to 100, against each ROC. Then these ratings could be multiplied by the weights obtained by the numerical evaluation

technique and summed to yield a weighted "effectiveness score". These scores consider the relative importance of the various ROC's as well as the ratings. The scores could then be used in a cost effectiveness study of the candidate vehicles.

Similarly, the technique could be applied by a contract proposal review committee or source selection board. The options could be various attributes of the contract porposal. The weighting process would yield the relative importance of the various attributes. Then each proposer could be rated against each attribute and the product of the rating and the weights could be summed for a total score.

There are almost a limitless number of situations in which the numerical evaluation technique could be applied. The principal strengths of the technique are:

1. It is simple.

2. It requires the decisionmaker to consider all options.

3. It is systematic. The same steps are always involved and proceed in a logical and unbiased manner.

4. It is very difficult to manipulate responses to obtain a preconceived answer.